Propagation Model Development & Comparisons

Outputs

- Comparison of algorithms used in ITM and TIREM models.
- Comparison of ITM and TIREM models to various measurement datasets.

ITS' work on propagation model development in FY 2002 focused on intercomparison and harmonization of the two radio frequency electromagnetic wave propagation models employed by the U.S. Government, the Irregular Terrain Model (ITM) and the Terrain Integrated Rough Earth Model (TIREM). This work was sponsored by NTIA's Office of Spectrum Management (OSM) and by ITS. Progress in each area for FY2002 is described below.

ITM & TIREM Intercomparison

ITM, developed by ITS, and TIREM, developed by OSM/IITRI, were very similar thirty years ago. Both models are based on NBS Technical Note 101.* ITM has remained virtually unchanged since the early/mid eighties, but TIREM has undergone many significant changes during the same time period.

ITM is an empirical model: its "deterministic" results are modified by comparisons to measured data to account for parameters that the model does not control. The set of measured data consists of over a dozen datasets containing more than 41,000 measurements, which span the frequency range from 20 to 10,000 MHz. Many different types of terrain (plains, hills, mountains, etc.) are included, and a wide variety of antenna heights and polarizations for the transmitter and receiver antennas were used to perform the measurements. If the data used to develop the empirical model cover all possible propagation situations, then the model should apply as a tool to perform radio-wave propagation predictions along any path. However, there are still propagation scenarios not contained in this database.

In FY 2001, ITS began a project to describe and compare the algorithms used in ITM and TIREM.

*P.L. Rice, A.G. Longley, K.A. Norton, and A.P. Barsis, "Transmission loss predictions for tropospheric communication circuits," NBS Technical Note 101, vols. 1 & 2, May 1965 (rev. May 1966 and Jan. 1967).

This work continued through FY 2002. Specifically, the algorithms for the line-of-sight (LOS), diffraction, and troposcatter regions are being examined, in addition to how each model utilizes an effective antenna height for these calculations. The final report will contain a summary of the results. It will provide a better understanding of these algorithms, propose explanations for why ITM and TIREM produce different answers, and suggest methods for obtaining the same answers with each model which also agree more closely with measured data.

ITM & TIREM Harmonization

During FY 2000, a study was launched to compare ITM v1.2.2 and TIREM v3.14 predictions to several measured radio propagation datasets. The major goals of this work, which continued throughout FY 2002, are to improve the predictive accuracies of ITM and TIREM, and to reduce or eliminate, where possible, differences between these two models' predictions for circuits with equivalent input values, all while preserving the increased predictive accuracies.

Difficulties arose when the results of two previous comparison studies were examined. The two studies considered data from datasets with substantial commonality and found comparable mean and variance statistics for the models' prediction errors. However, examination of the results for individual paths revealed large differences in the detailed comparisons of the predictions for a given model (TIREM) between the two studies. Furthermore, there was evidence from the data that both the measurements and the predictions, and, hence, the prediction errors, were subject to significant correlation. Computation of meaningful statistics in the presence of correlated data was a major problem encountered in this study.

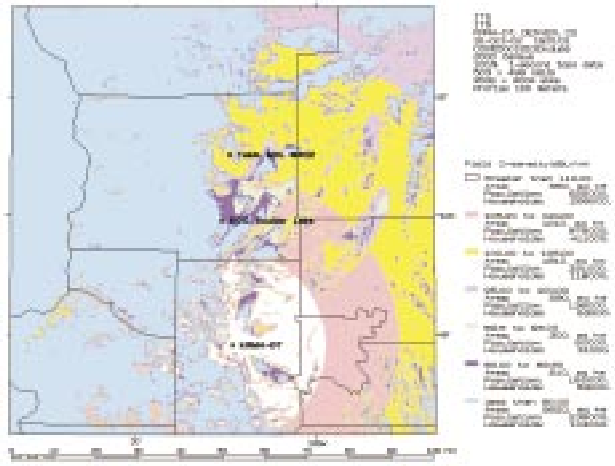
ITS has proposed a mechanism for the data correlation and tested it on several datasets. Results show substantial correlation in the data and the statistics are affected by this correlation. This data correlation is due to many of the measurements having been made at multiple frequencies and antenna heights on the same path. When propagation conditions for the measurements and hence predictions were found to be good or bad for a particular path, they were good or bad for all frequencies and antenna heights along the path. Univariate statistical analysis of the data relies on data samples in which the individual measurements have been randomly drawn from a large universe of radio-wave propagation measurements. These samples should be independent and have identical frequency distribution. When the data samples are correlated, this independence assumption is violated.

It is necessary to eliminate this correlation. As our model, the measurements on one path are considered to be independent of measurements taken on another path. The excess loss relative to free space predicted by ITM was compared to the measured data, and the difference was used as the statistical random variable. By segregating the data so that it is taken from different paths, a multivariate statistical analysis can proceed. This enables testing the significance of the distribution of the means, medians, and standard deviations of the difference between model loss predictions and measured data. These results will aid the harmonization effort for the two propagation prediction models.

Effective Antenna Height Study

ITM uses effective antenna heights throughout most of the program (except when computing horizon elevation angles, distances to horizons, and Fresnel zone clearances), while TIREM uses structural heights exclusively. This difference has a significant impact on propagation loss predictions. Thus, the correct value of reference attenuation depends on the values of effective antenna height. Effective antenna height changes the predicted propagation loss by as much as 45 dB relative to predictions using only a structural height. Transmitter and receiver effective antenna heights above the dominant reflecting plane are computed by an algorithm within ITM. The effective antenna heights along the propagation path are determined from the terrain contour, the structural antenna heights above ground level, and the distances to the horizon from each of the antennas.

ITM was used to examine propagation paths found in the measured data. In one case, the ITM effective antenna height algorithm was used to select the effective antenna height. In a second case, the effective antenna height was fixed at the structural height. Propagation loss predictions were made for most propagation paths in the database. The predicted value of propagation loss was compared with the measured value for both cases. The loss deviation is the predicted value of attenuation from the model minus the measured value of attenuation.



Example of the use of ITM to predict electric field strength for a proposed digital television broadcast antenna on Lookout Mountain near Golden, CO. The predictions were made using USGS 1" terrain data.

The comparison of ITM predictions to measured data has generated a number of different behavior characteristics related to the internal computation of effective antenna height being investigated. This investigation will provide guidance in selecting an improved effective antenna height computation. In some cases, ITM computes a large effective antenna height that differs substantially from the structural height, resulting in a large deviation between the value of predicted and measured transmission loss. There are cases where, if the effective antenna height were made equal to the structural height, then the deviation can be reduced, but in just as many cases large deviation occurs. That is, many cases exist where the deviation resulting from measured paths using the structural height is much larger than the deviation for the measured paths using the effective height. There are also many measured paths where the optimum value of effective antenna height is somewhere between the ITM-determined effective antenna height and the actual structural antenna height. The effective antenna height is always greater than or equal to the structural height. Further study of the behavior of ITM in different scenarios will provide information for the development of a new effective antenna height algorithm that minimizes the deviation between predicted and measured propagation loss.

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